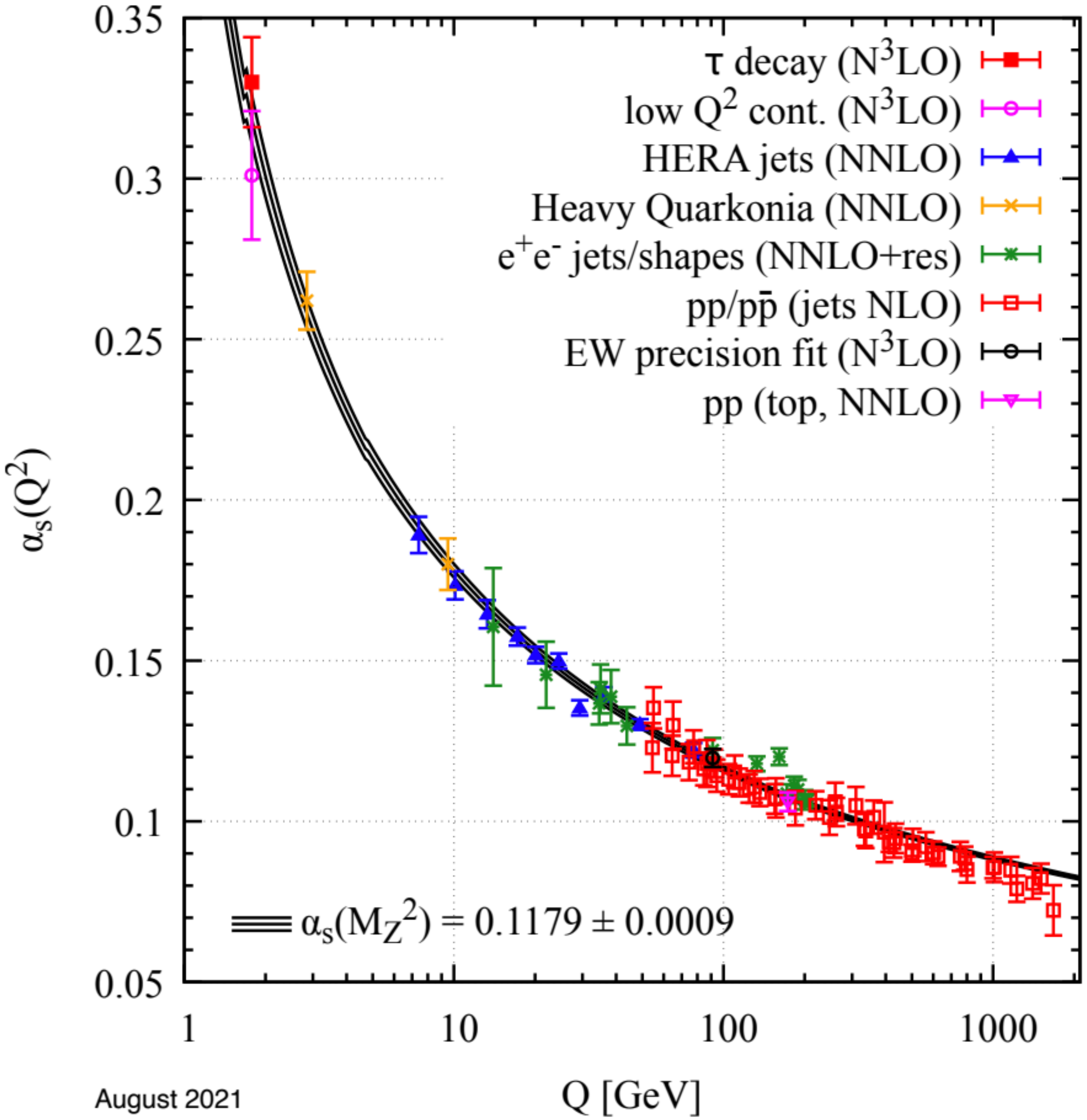
RUNNING COUPLING

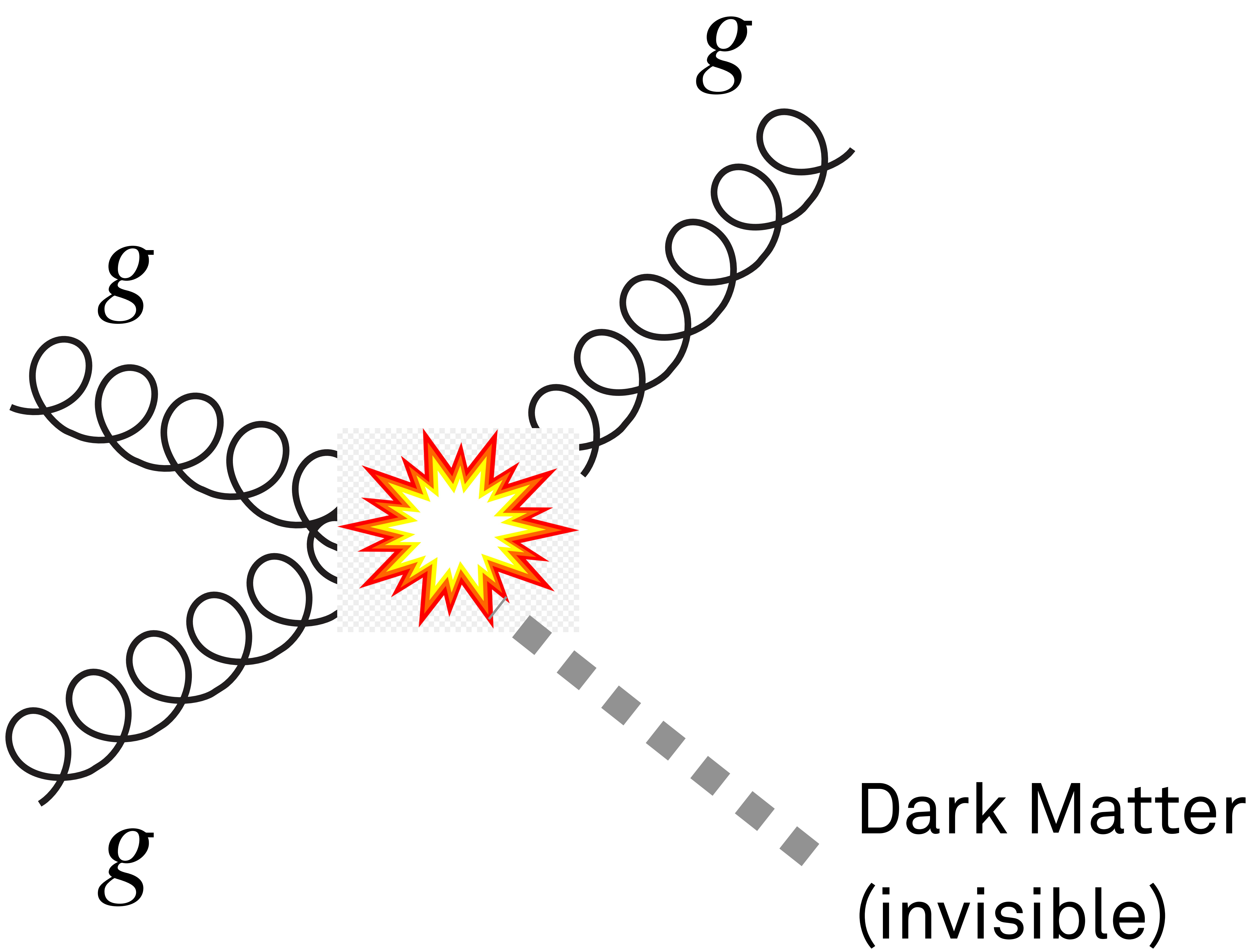


August 2021

PDG

DARK MATTER @ LHC

MONO-X

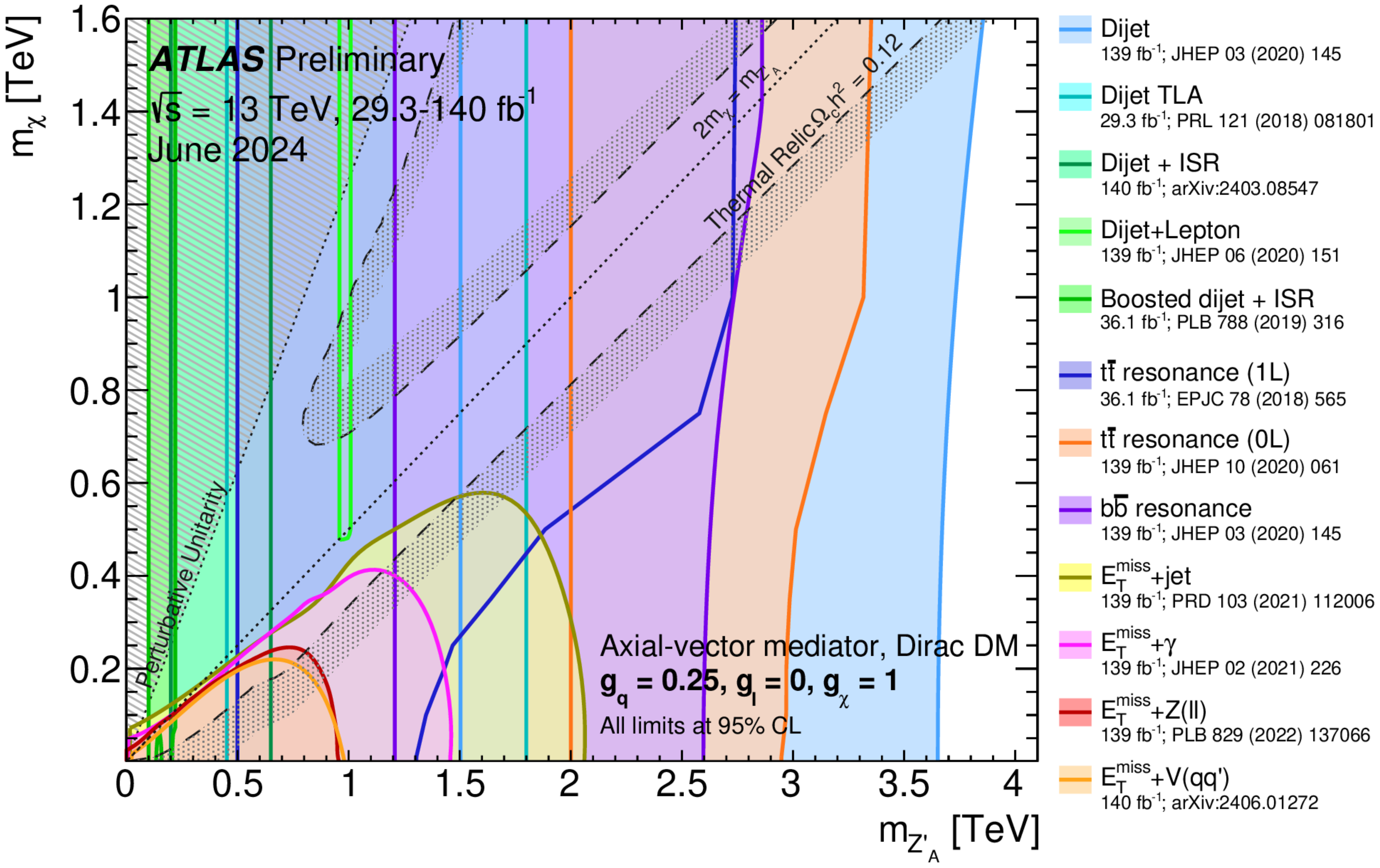


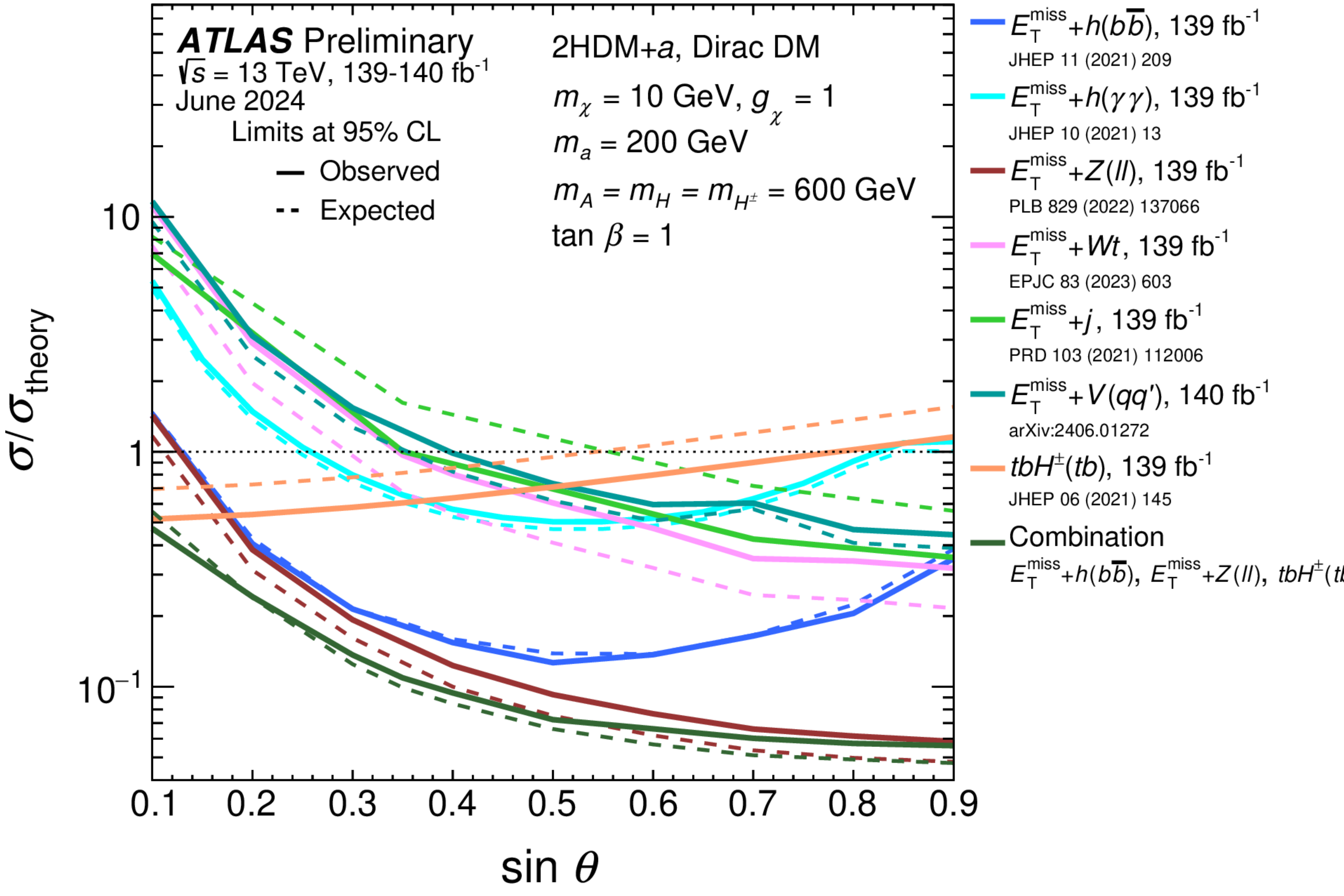
Look for 1 jet (quark or gluon) + missing energy.

Model agnostic search for many dark matter models.

arXiv:1008.1783.
arXiv:1109.4398.

MONO-X





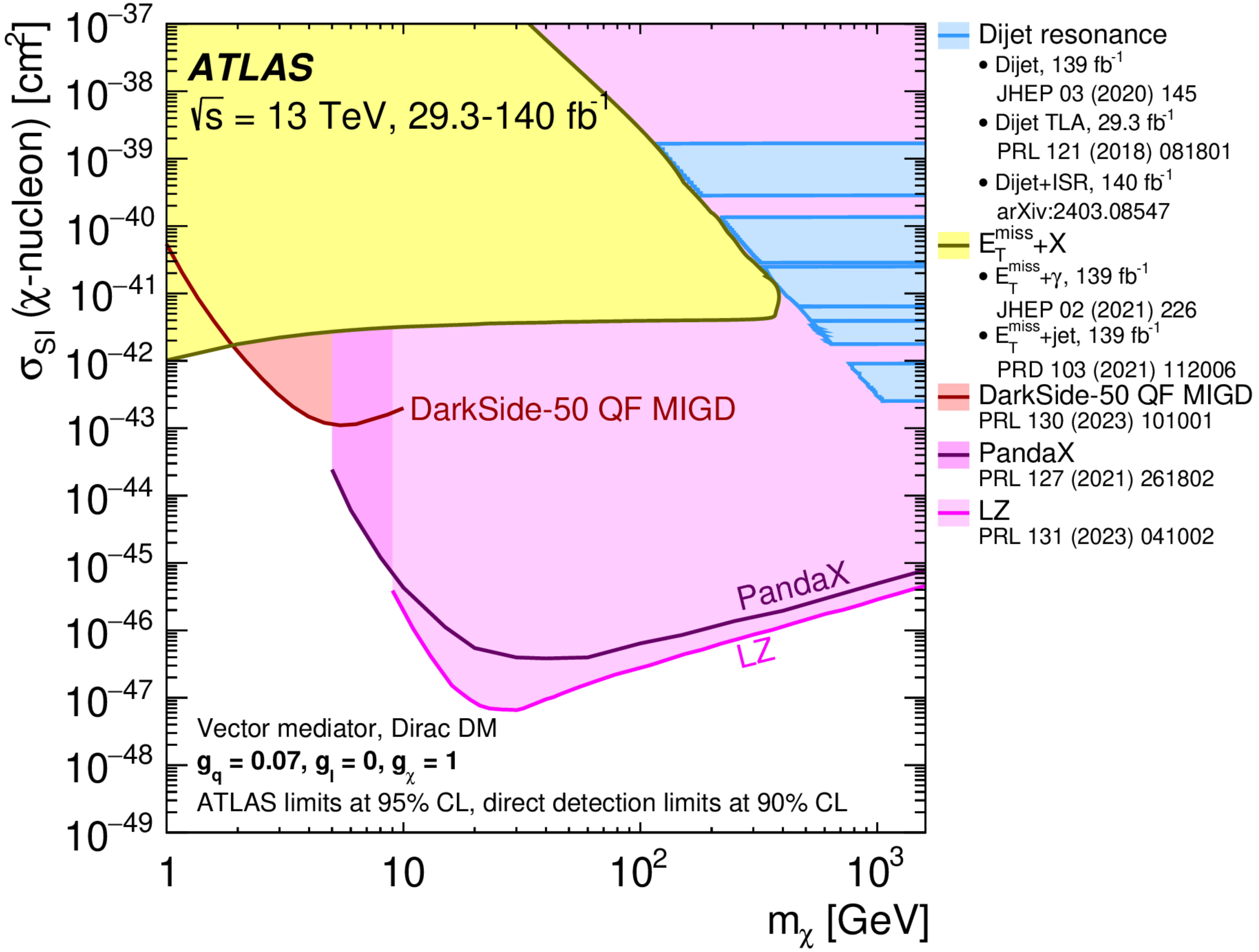
Can take all searches and use them to constrain specific models.

COMPARE TO DIRECT DETECTION

How does this compare to dark matter direct detections (lectures by Diamond, Hong, Wenz)?

Very different energy regime!

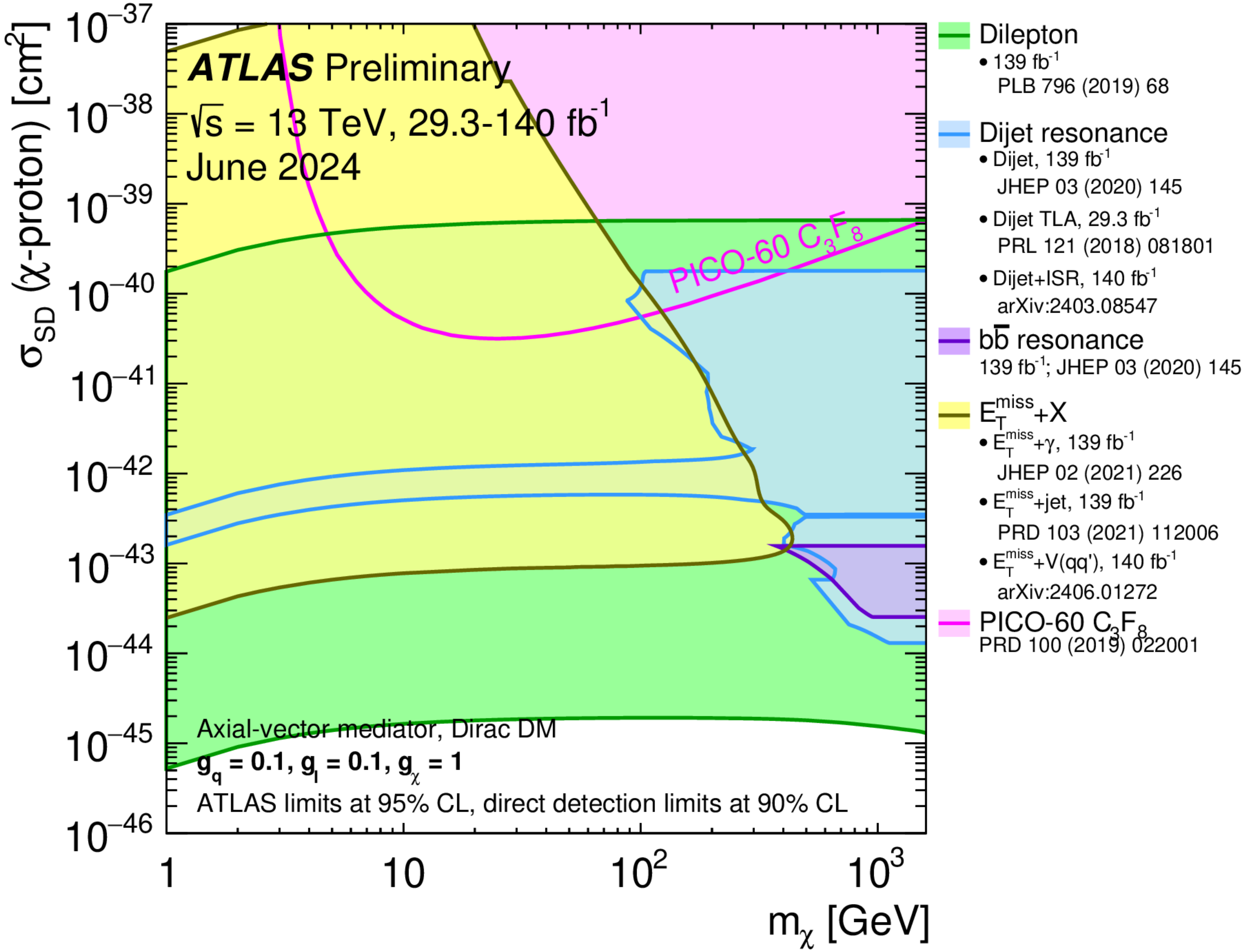
Collider better at low energy, DD wins at high energy.



COMPARE TO DIRECT DETECTION

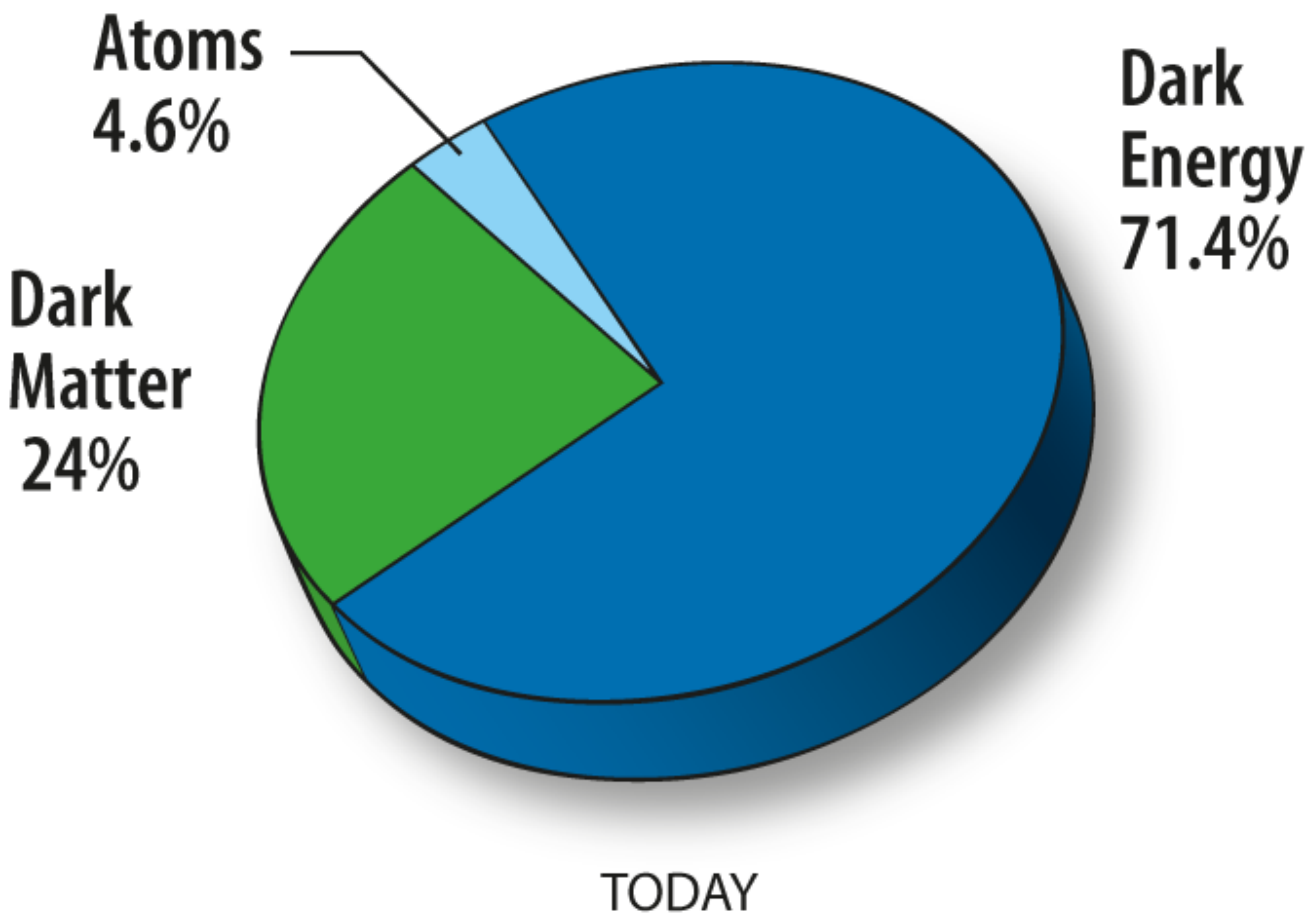
Very model dependant!

Two methods are complementary.



PROFESSOR DARK MATTER

THOUGHT EXPERIMENT

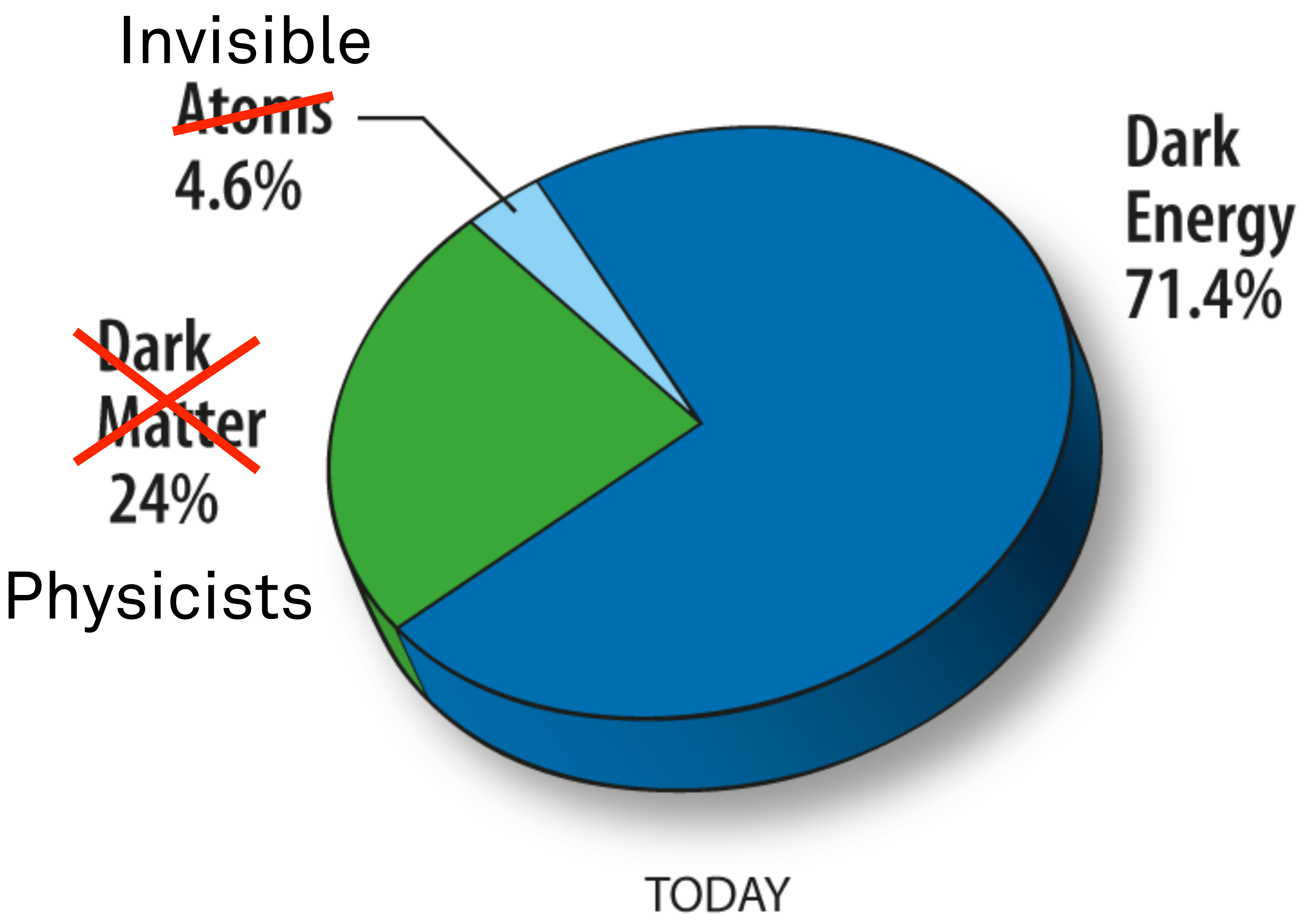


They ask, where is the missing 5%?

Most theorists will posit a single “dark matter” particle.

h/t Neal Weiner

THOUGHT EXPERIMENT



They ask, where is the missing 5%?

Most theorists will posit a single “dark matter” particle.

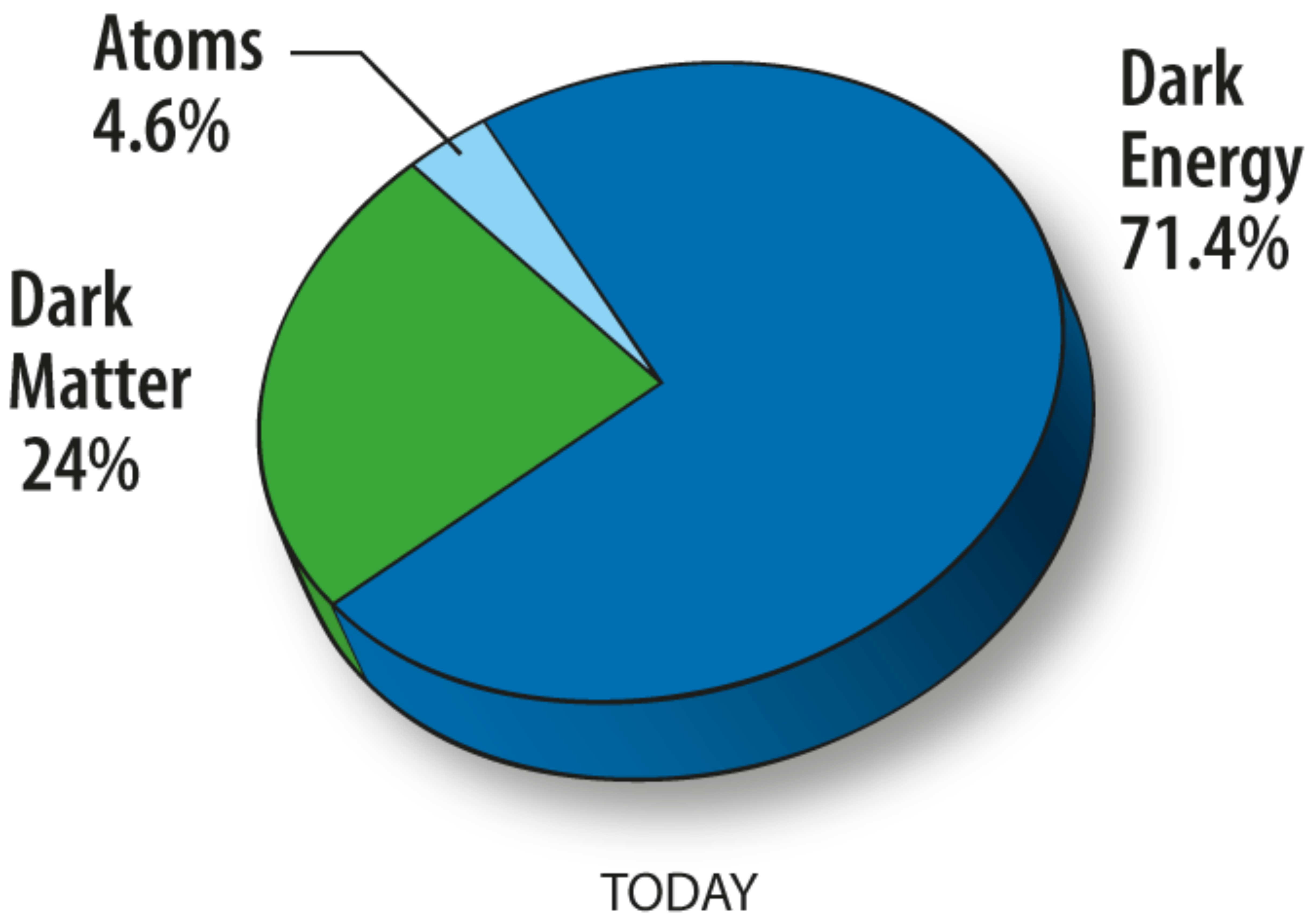
h/t Neal Weiner

THOUGHT EXPERIMENT

h/t Neal Weiner

$$\begin{gathered}
\mathcal{L}_{SM} = -\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g_s^2 f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - \\
M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \tfrac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu - \tfrac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - igc_w(\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)) - \\
igs_w(\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - \\
W^-_\nu\partial_\nu W^+_\mu)) - \tfrac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - \\
Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w(A_\mu Z^0_\nu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu) - \tfrac{1}{2}\partial_\mu H\partial_\mu H - 2M^2\alpha_h H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - \tfrac{1}{2}\partial_\mu\phi^0\partial_\mu\phi^0 - \\
\beta_h\left(\tfrac{2M^2}{g^2} + \tfrac{2M}{g}H + \tfrac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^+\phi^-)\right) + \tfrac{2M^4}{g^2}\alpha_h - \\
g\alpha_h M\,(H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-) - \\
\tfrac{1}{8}g^2\alpha_h\,(H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2) - \\
gMW^+_\mu W^-_\mu H - \tfrac{1}{2}g\tfrac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \\
\tfrac{1}{2}ig\left(W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)\right) + \\
\tfrac{1}{2}g\left(W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) + W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)\right) + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) + \\
M\,(\tfrac{1}{c_w}Z^0_\mu\partial_\mu\phi^0 + W^+_\mu\partial_\mu\phi^- + W^-_\mu\partial_\mu\phi^+) - ig\tfrac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + igs_wMA_\mu(W^+_\mu\phi^- - \\
W^-_\mu\phi^+) - ig\tfrac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) + igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \\
\tfrac{1}{4}g^2W^+_\mu W^-_\mu\,(H^2 + (\phi^0)^2 + 2\phi^+\phi^-) - \tfrac{1}{8}g^2\tfrac{1}{c_w^2}Z^0_\mu Z^0_\mu\,(H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2\phi^+\phi^-) - \\
\tfrac{1}{2}g^2\tfrac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) - \tfrac{1}{2}ig^2\tfrac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \tfrac{1}{2}g^2s_wA_\mu\phi^0(W^+_\mu\phi^- + \\
W^-_\mu\phi^+) + \tfrac{1}{2}ig^2s_wA_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\tfrac{s_w}{c_w}(2c_w^2 - 1)Z^0_\mu A_\mu\phi^+\phi^- - \\
g^2s_w^2A_\mu A_\mu\phi^+\phi^- + \tfrac{1}{2}ig_s\,\lambda^a_{ij}(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu - \bar{e}^\lambda(\gamma\partial + m^\lambda_e)e^\lambda - \bar{\nu}^\lambda(\gamma\partial + m^\lambda_\nu)\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + \\
m^\lambda_u)u^\lambda_j - \bar{d}^\lambda_j(\gamma\partial + m^\lambda_d)d^\lambda_j + igs_wA_\mu\left(-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)\right) + \\
\tfrac{ig}{4c_w}Z^0_\mu\{(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar{d}^\lambda_j\gamma^\mu(\tfrac{4}{3}s_w^2 - 1 - \gamma^5)d^\lambda_j) + \\
(\bar{u}^\lambda_j\gamma^\mu(1 - \tfrac{8}{3}s_w^2 + \gamma^5)u^\lambda_j)\} + \tfrac{ig}{2\sqrt{2}}W^+_\mu\left((\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)U^{lep}{}_{\lambda\kappa}e^\kappa) + (\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)\right) + \\
\tfrac{ig}{2\sqrt{2}}W^-_\mu\left((\bar{e}^\kappa U^{lep\dagger}{}_{\kappa\lambda}\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\kappa\lambda}\gamma^\mu(1+\gamma^5)u^\lambda_j)\right) + \\
\tfrac{ig}{2M\sqrt{2}}\phi^+\left(-m^\kappa_e(\bar{\nu}^\lambda U^{lep}{}_{\lambda\kappa}(1-\gamma^5)e^\kappa) + m^\lambda_\nu(\bar{\nu}^\lambda U^{lep}{}_{\lambda\kappa}(1+\gamma^5)e^\kappa\right) + \\
\tfrac{ig}{2M\sqrt{2}}\phi^-\left(m^\lambda_e(\bar{e}^\lambda U^{lep\dagger}{}_{\lambda\kappa}(1+\gamma^5)\nu^\kappa) - m^\kappa_\nu(\bar{e}^\lambda U^{lep\dagger}{}_{\lambda\kappa}(1-\gamma^5)\nu^\kappa\right) - \tfrac{g}{2}\tfrac{m^\lambda_\nu}{M}H(\bar{\nu}^\lambda\nu^\lambda) - \\
\tfrac{g}{2}\tfrac{m^\lambda_e}{M}H(\bar{e}^\lambda e^\lambda) + \tfrac{ig}{2}\tfrac{m^\lambda_\nu}{M}\phi^0(\bar{\nu}^\lambda\gamma^5\nu^\lambda) - \tfrac{ig}{2}\tfrac{m^\lambda_e}{M}\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda) - \tfrac{1}{4}\,\bar{\nu}_\lambda\,M^R_{\lambda\kappa}\,(1-\gamma_5)\hat{\nu}_\kappa - \\
\tfrac{1}{4}\,\bar{\nu}_\lambda\,M^R_{\lambda\kappa}\,(1-\gamma_5)\hat{\nu}_\kappa + \tfrac{ig}{2M\sqrt{2}}\phi^+\left(-m^\kappa_d(\bar{u}^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) + m^\lambda_u(\bar{u}^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j\right) + \\
\tfrac{ig}{2M\sqrt{2}}\phi^-\left(m^\lambda_d(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m^\kappa_u(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1-\gamma^5)u^\kappa_j\right) - \tfrac{g}{2}\tfrac{m^\lambda_u}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \\
\tfrac{g}{2}\tfrac{m^\lambda_d}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2}\tfrac{m^\lambda_u}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) - \tfrac{ig}{2}\tfrac{m^\lambda_d}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) + \bar{G}^a\partial^2G^a + g_sf^{abc}\partial_\mu\bar{G}^aG^bg^c_\mu + \\
\bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 - \tfrac{M^2}{c_w^2})X^0 + \bar{Y}\partial^2Y + igc_wW^+_\mu(\partial_\mu\bar{X}^0X^- - \\
\partial_\mu\bar{X}^+X^0) + igs_wW^+_\mu(\partial_\mu\bar{Y}X^- - \partial_\mu\bar{X}^+Y) + igc_wW^-_\mu(\partial_\mu\bar{X}^-X^0 - \\
\partial_\mu\bar{X}^0X^+) + igs_wW^-_\mu(\partial_\mu\bar{X}^-Y - \partial_\mu\bar{Y}X^+) + igc_wZ^0_\mu(\partial_\mu\bar{X}^+X^+ - \\
\partial_\mu\bar{X}^-X^-) + igs_wA_\mu(\partial_\mu\bar{X}^+X^+ - \\
\partial_\mu\bar{X}^-X^-) - \tfrac{1}{2}gM\left(\bar{X}^+X^+H + \bar{X}^-X^-H + \tfrac{1}{c_w^2}\bar{X}^0X^0H\right) + \tfrac{1-2c_w^2}{2c_w}igM\left(\bar{X}^+X^0\phi^+ - \bar{X}^-X^0\phi^-\right) + \\
\tfrac{1}{2c_w}igM\left(\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-\right) + igMs_w\left(\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-\right) + \\
\tfrac{1}{2}igM\left(\bar{X}^+X^+\phi^0 - \bar{X}^-X^-\phi^0\right)\,.
\end{gathered}$$

THOUGHT EXPERIMENT



Dark matter could be part of a complicated sector with interesting dynamics! (see lectures by Shandera)

h/t Neal Weiner

ASYMMETRIC DARK MATTER

$$\Omega_{DM} \simeq 5\Omega_B$$

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$$\Omega_{DM} = m_{DM} n_{DM} \qquad\qquad \Omega_B = m_p n_B$$

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Controlled by complicated (known) QCD dynamics

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Unknown dynamics of baryogenesis

ASYMMETRIC DARK MATTER

$$\Omega_{DM} \simeq 5\Omega_B$$

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$$\Omega_{DM} = m_{DM} n_{DM} \qquad \Omega_B = m_p n_B$$

?

Unknown dynamics of baryogenesis

ASYMMETRIC DARK MATTER

$$\Omega_{DM} \simeq 5\Omega_B$$

$$\Omega_{DM} = m_{DM} n_{DM} \qquad \Omega_B = m_p n_B$$

?

Unknown dynamics of baryogenesis

Can get $n_{DM} \sim n_B$, usually have to assume $m_{DM} \sim m_B$.

ASYMMETRIC DARK MATTER

$$\Omega_{DM} \simeq 5\Omega_B$$

$$\Omega_{DM} = m_{DM} n_{DM} \qquad \Omega_B = m_p n_B$$

?

Unknown dynamics of baryogenesis

Can get $n_{DM} \sim n_B$, usually have to assume $m_{DM} \sim m_B$.

Can we get both?

GETTING THE MASS

$$\Omega_{DM} \simeq 5\Omega_B$$

Controlled by complicated (known) QCD dynamics

$$\Omega_{DM} = m_{DM} n_{DM} \qquad \Omega_B = m_p n_B$$

?

Unknown dynamics of baryogenesis

GETTING THE MASS

$$\Omega_{DM} \simeq 5\Omega_B$$

QCD like

?

Controlled by complicated (known) QCD dynamics

$$\Omega_{DM} = m_{DM} n_{DM}$$

$$\Omega_B = m_p n_B$$

?

Unknown dynamics of baryogenesis

DARK QCD

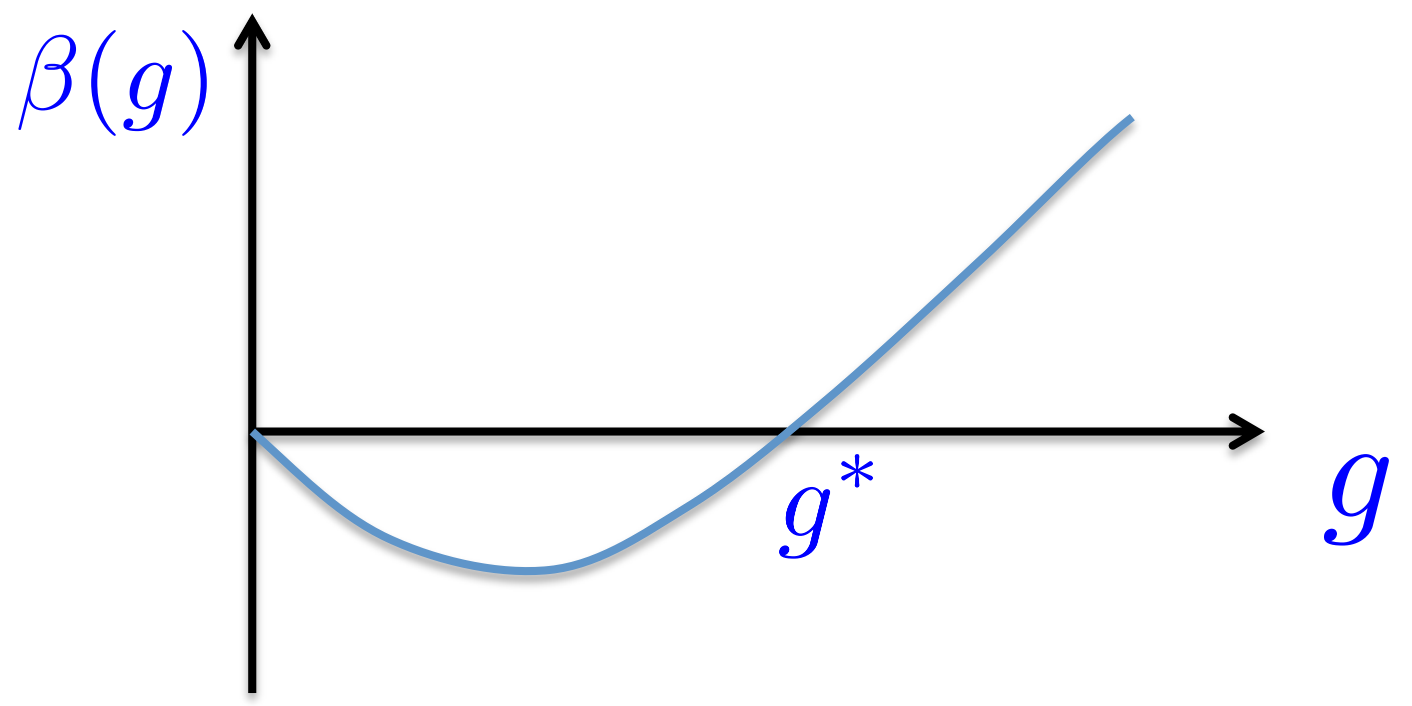
Propose new SU(N_d) “dark QCD,” dark quarks.
Bai, Schwaller, 1306.4676.

Dark matter is dark sector baryons with mass ~$\Lambda_{\rm dQCD}$.

Massive bifundamental fields decouple at mass M >> $\Lambda_{\rm dQCD}$.

Search for model with perturbative fixed point.

$$\frac{dg}{dt} = \beta(g) = 0 \text{ for } g = g^*$$



ASYMMETRY SHARING

Can co-generate DM and baryon asymmetry.

$$\bar{Q}\, X\, d_i$$

Asymmetries for baryons and dark matter are (roughly) equal.

ASYMMETRY SHARING

Can co-generate DM and baryon asymmetry.

$$\bar{Q}\, X\, d_i$$

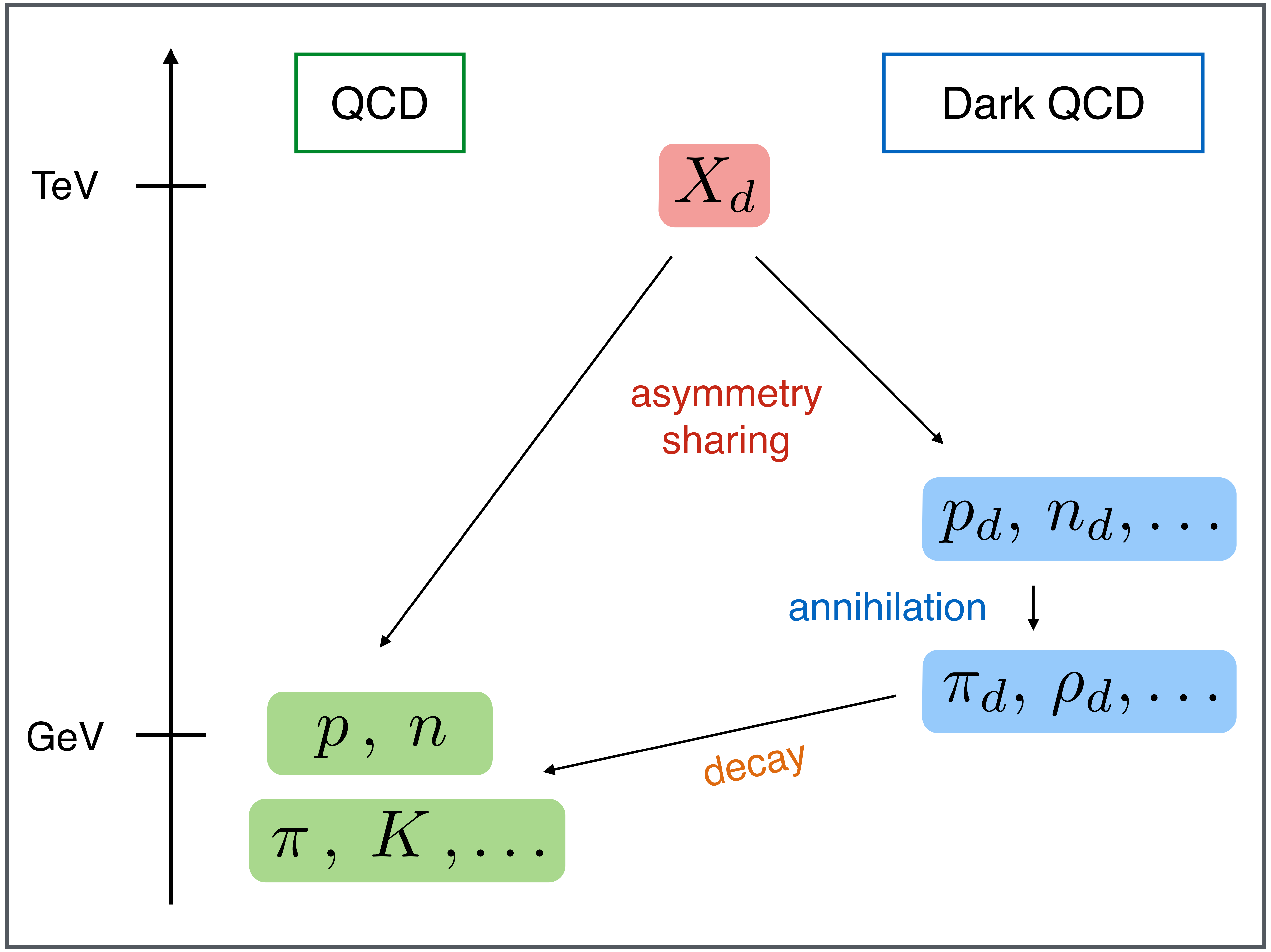
d_i → SM quark

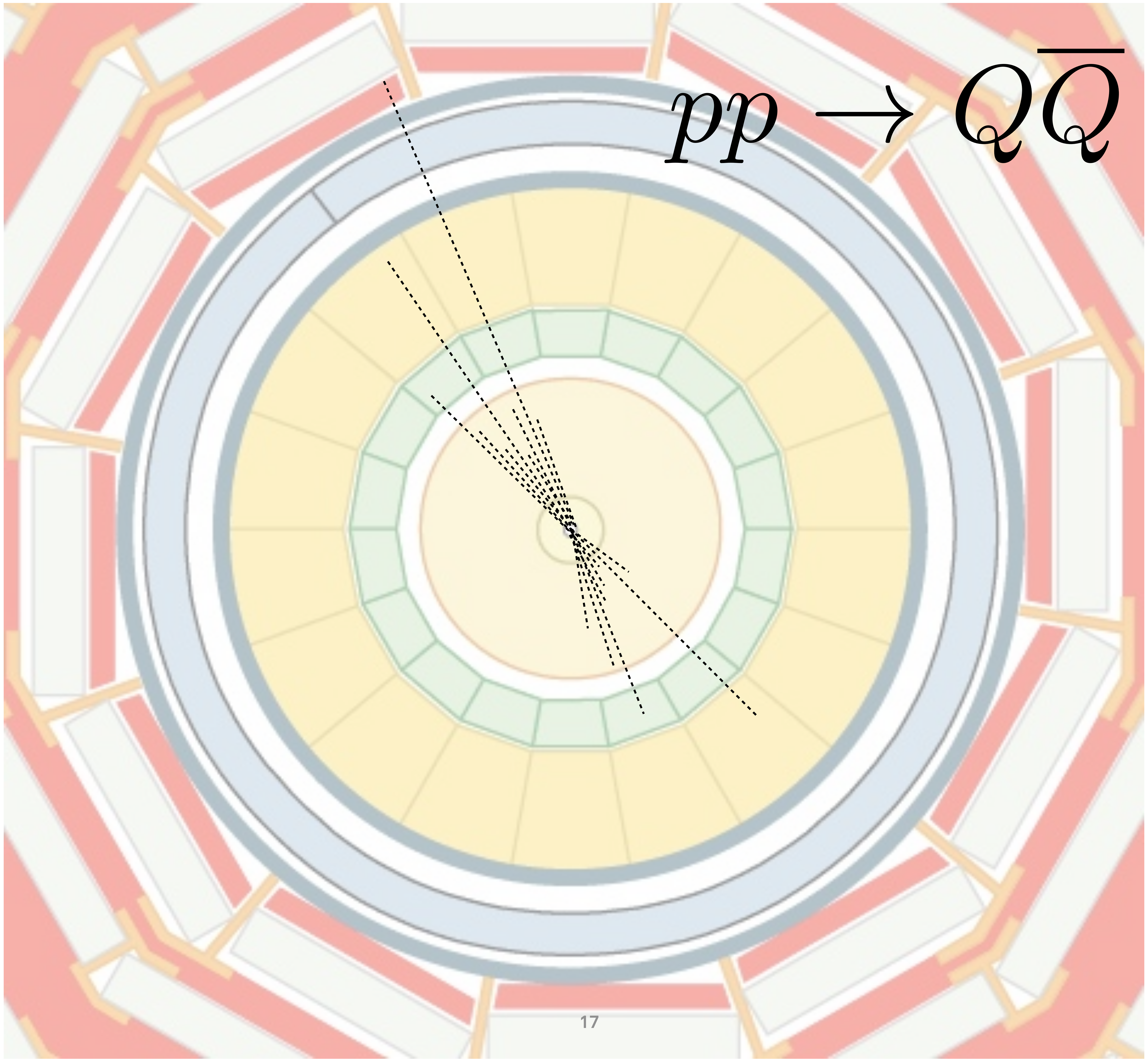
X → bifundamental scalar

$\bar{Q}$ → dark quark

Asymmetries for baryons and dark matter are (roughly) equal.

GENERAL PICTURE

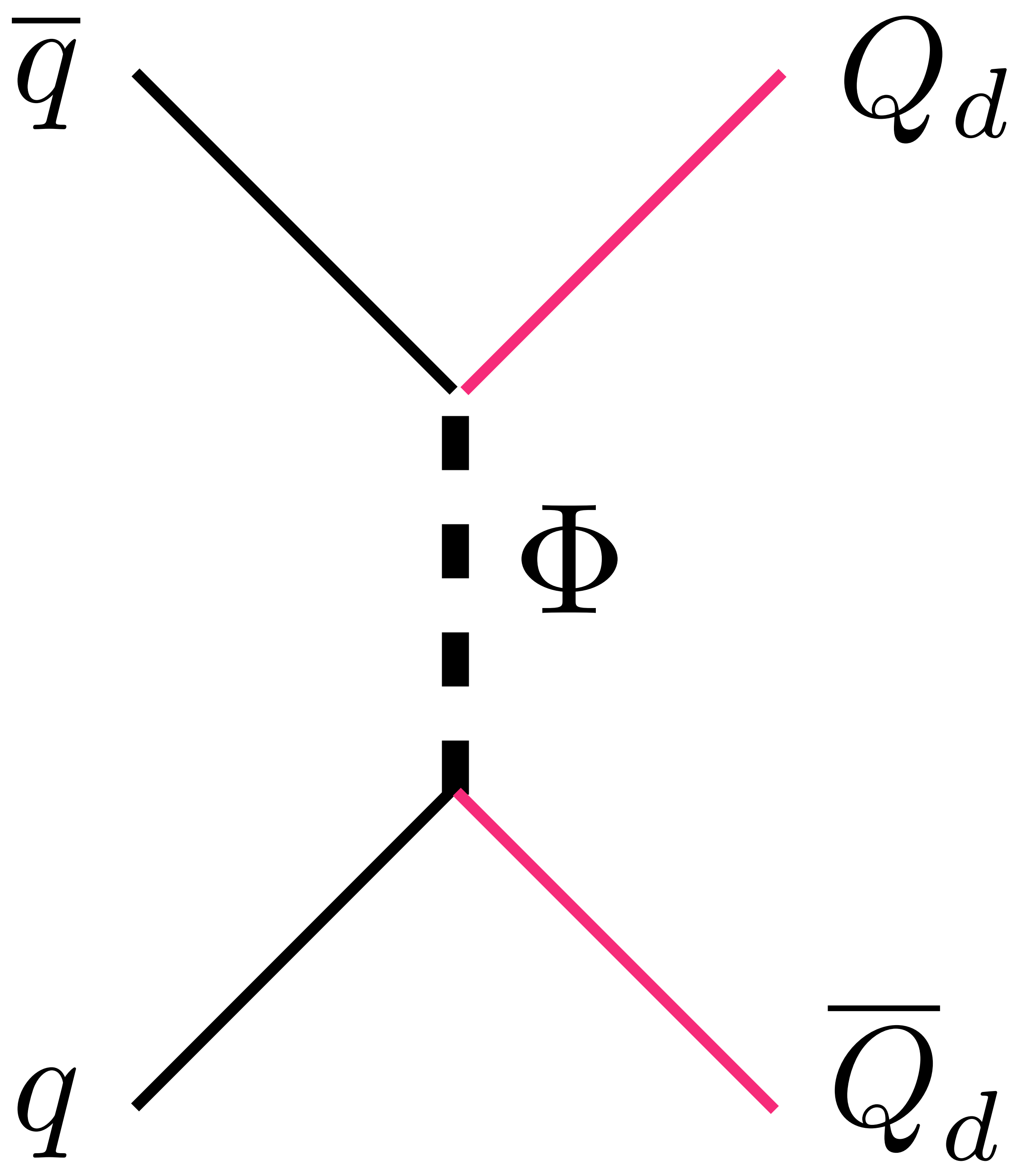



$pp \to Q\overline{Q}$

PION DECAY

Operator used to generate asymmetry mediates decay:

$$\bar{Q}\, X\, d_i$$

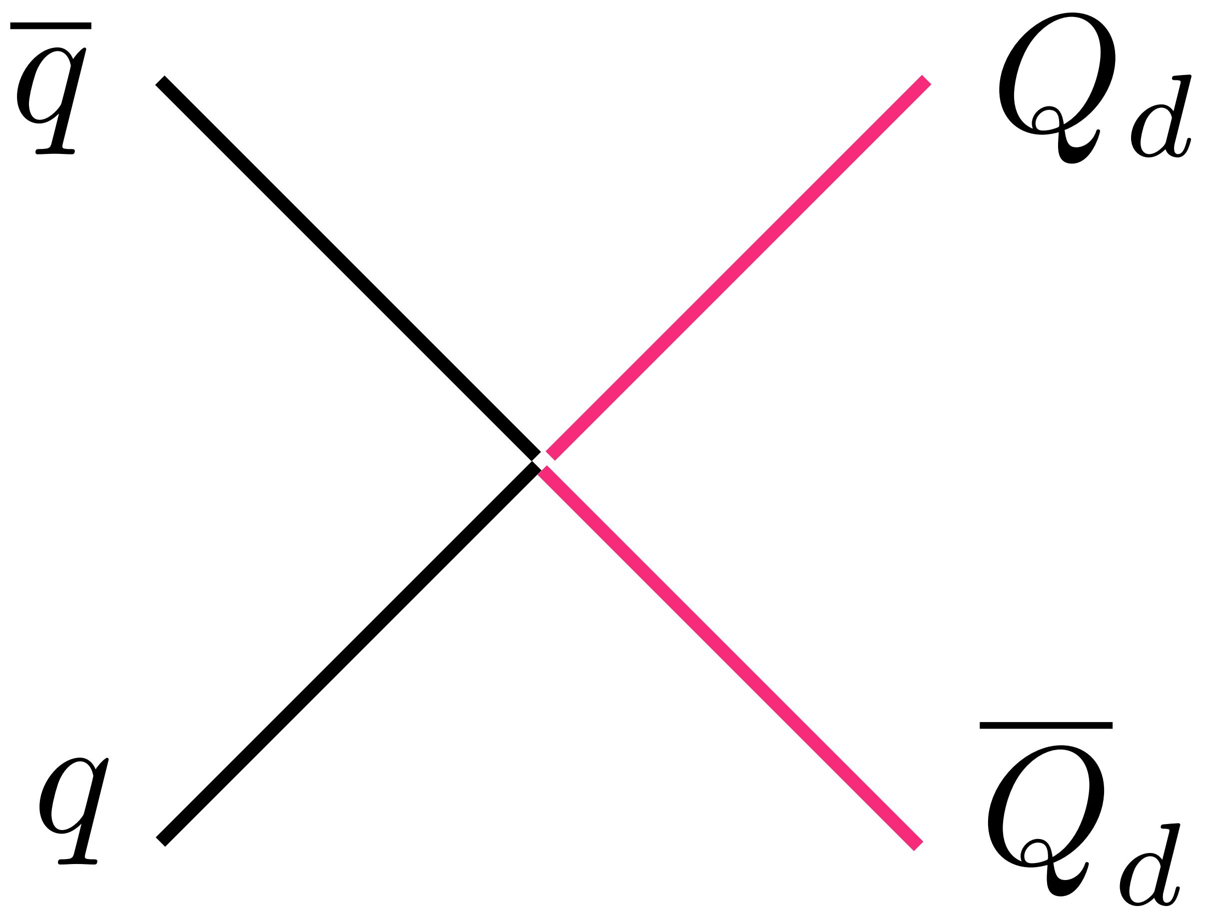


PION DECAY

Operator used to generate asymmetry mediates decay:

$$\bar{Q}\, X\, d_i$$

Integrate out X.



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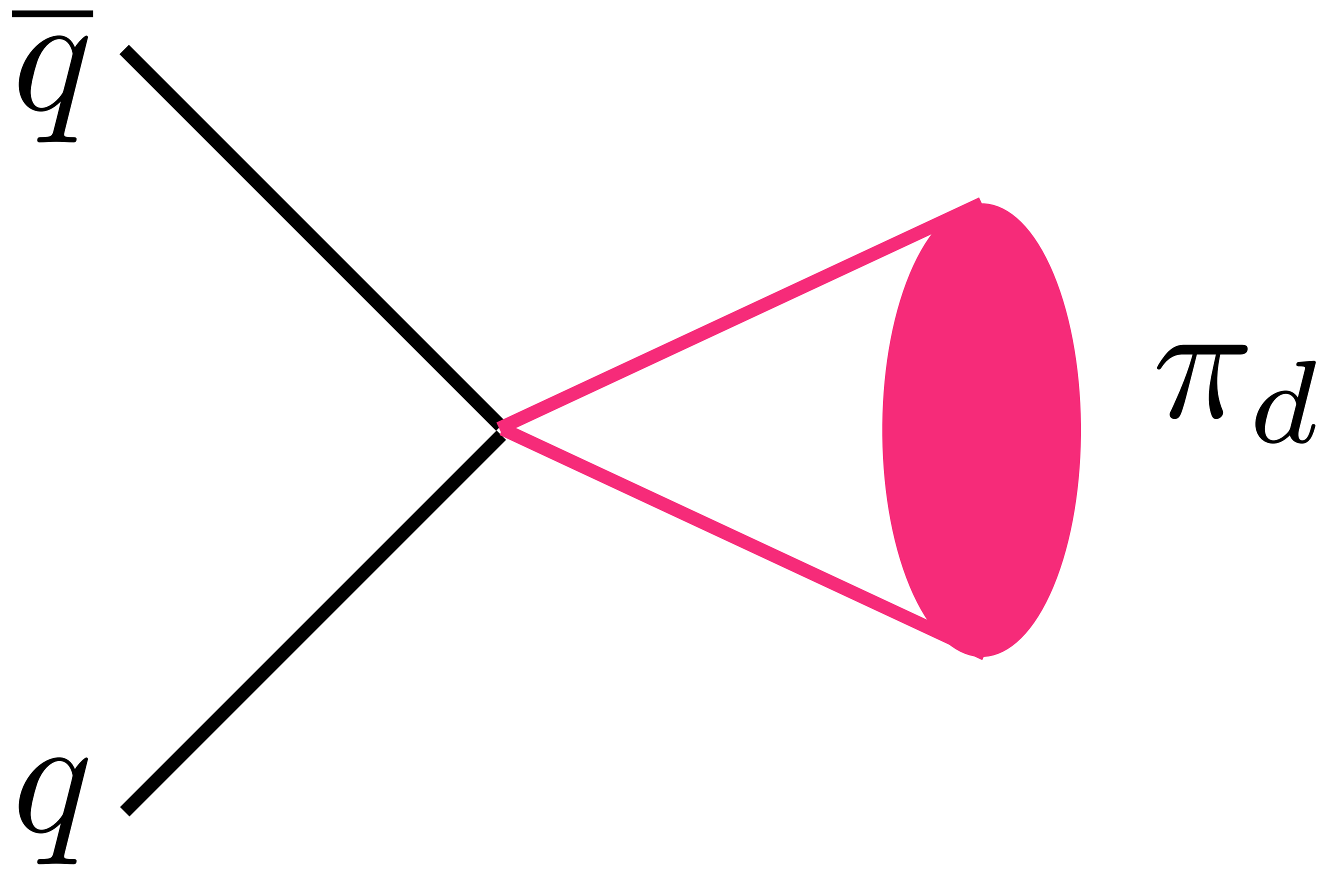
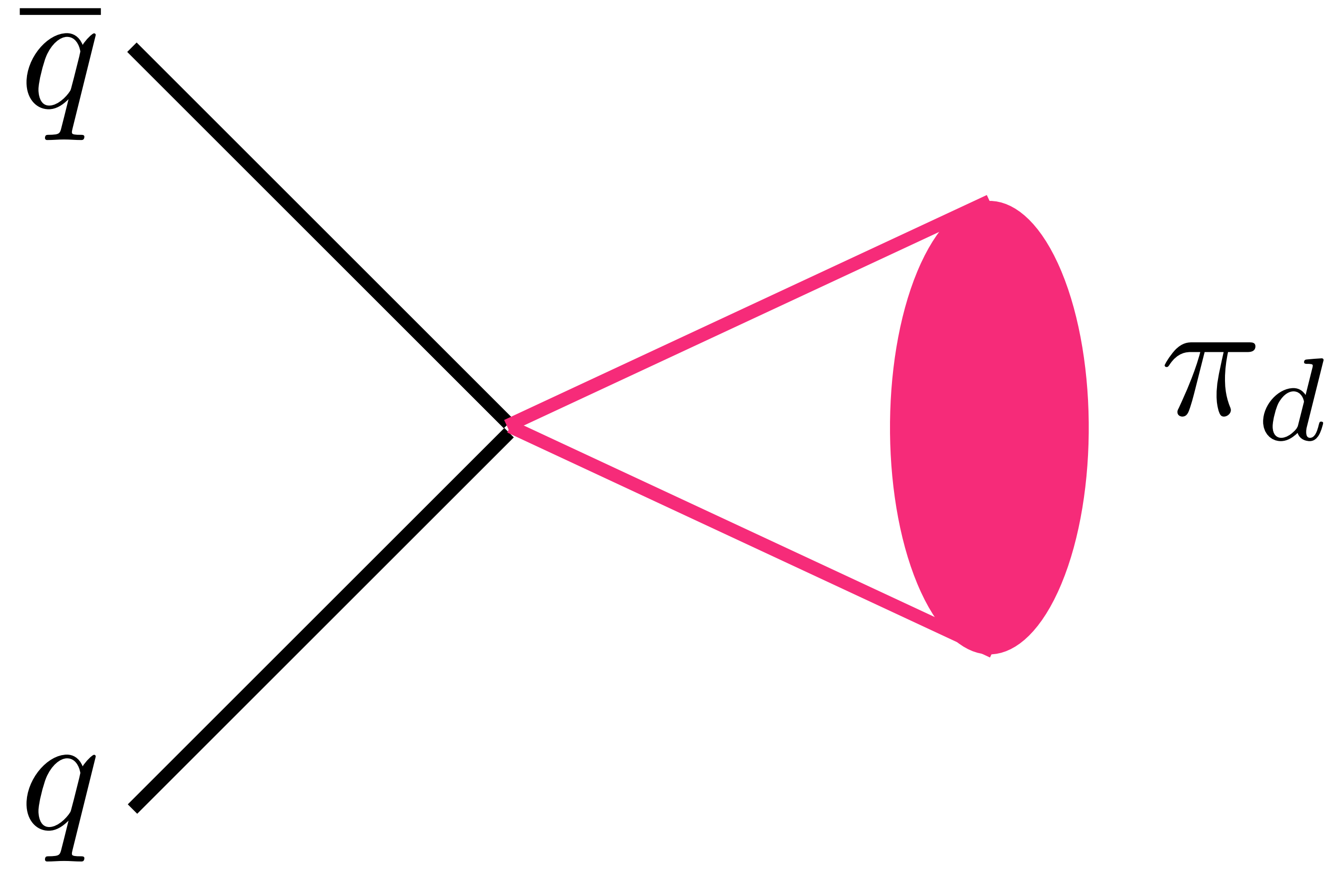


Dark pion decays to quarks

DECAY LENGTH

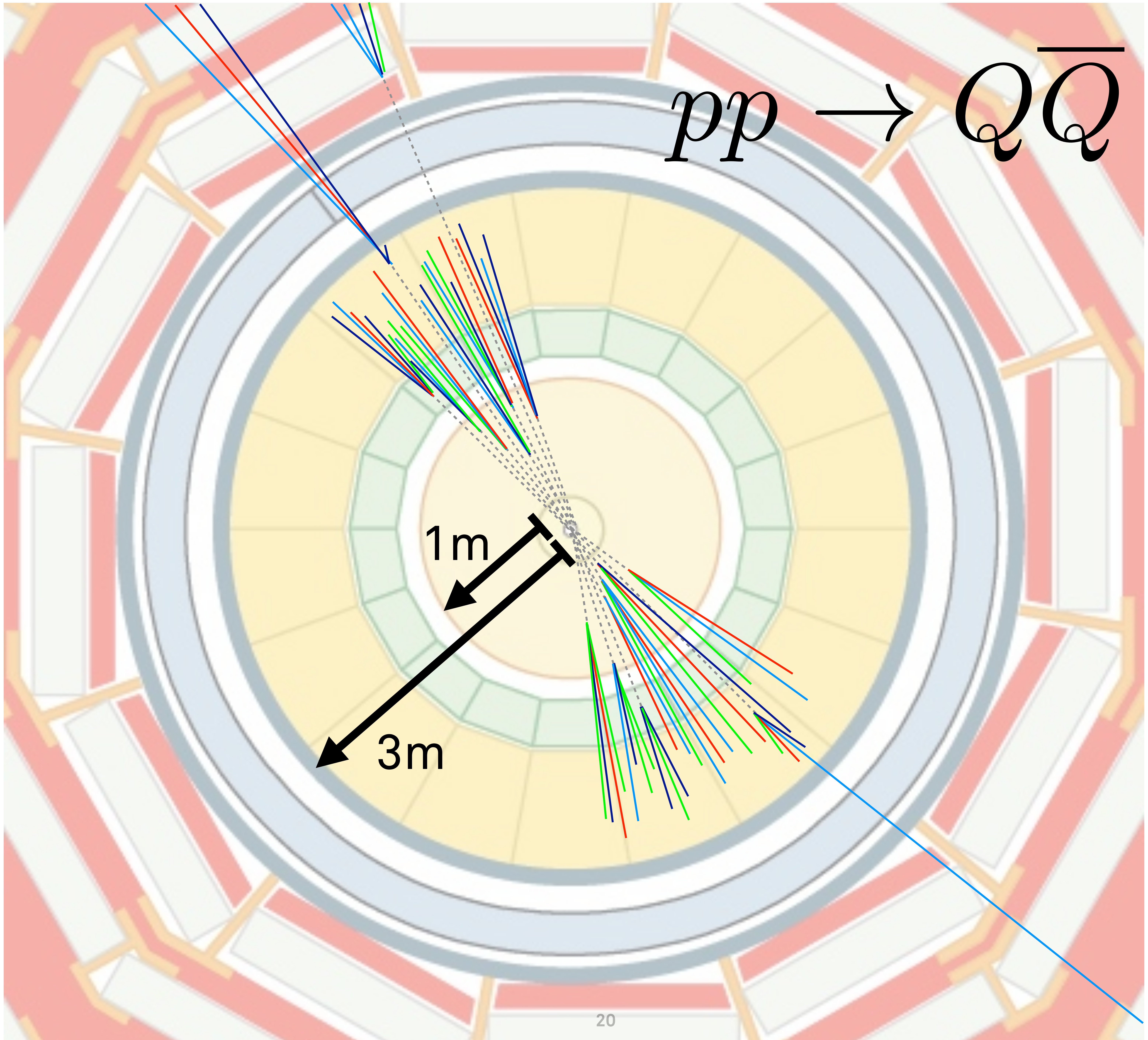


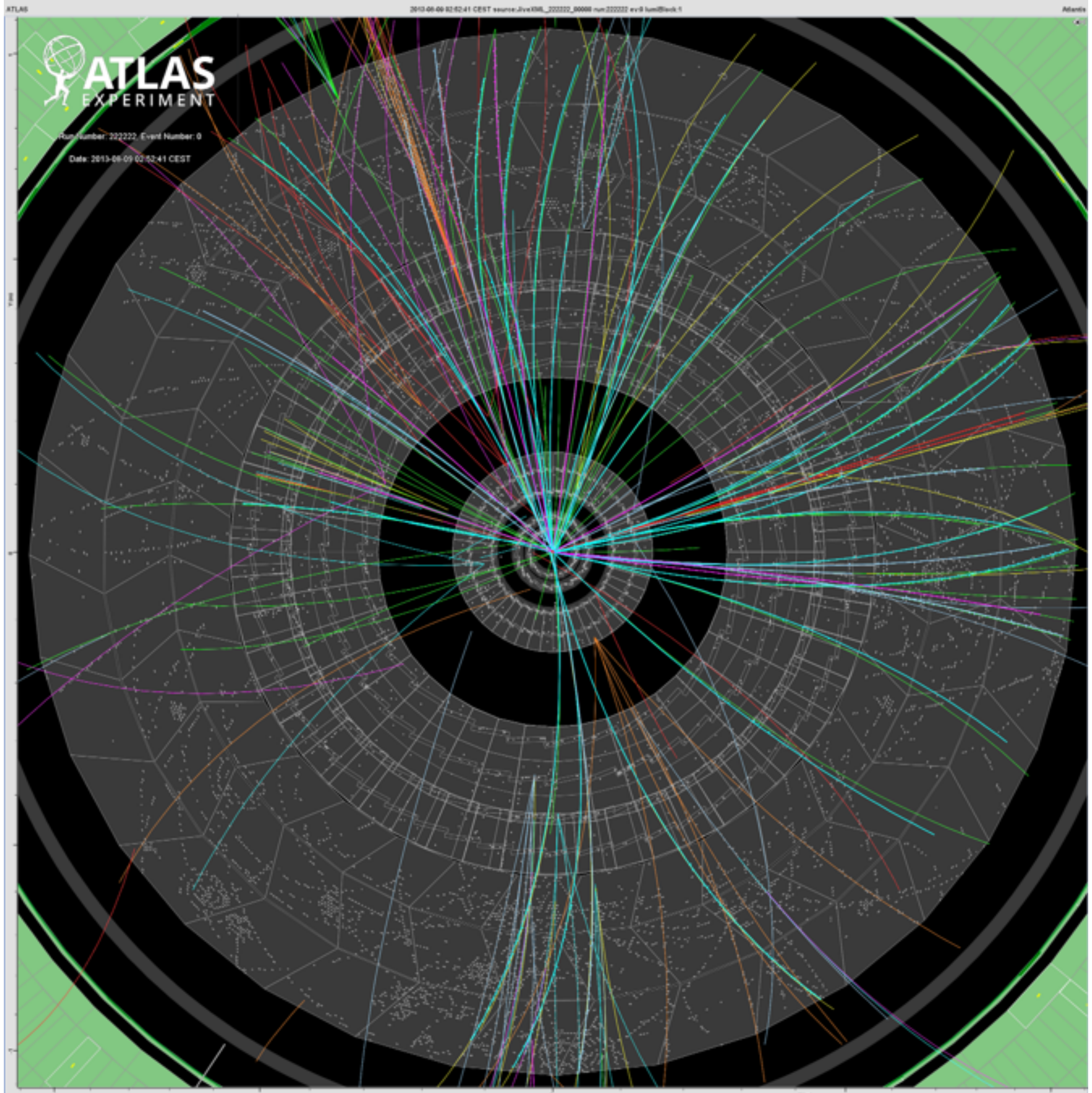
$$\frac{1}{M_X^2}\overline{Q}\gamma_\mu Q\,\bar{d}_R\gamma^\mu d_R$$

Can use (dark) chiral Lagrangian to estimate:

$$\Gamma(\pi_d \to \bar{d}d) \approx \frac{f_{\pi_d}^2 m_{\rm d}^2}{32\pi M_{X_d}^4} m_{\pi_d}$$

$$c\tau_0 \approx 10\,\text{cm} \times \left(\frac{2\text{ GeV}}{f_{\pi_d}}\right)^2 \left(\frac{100\text{ MeV}}{m_{\rm down}}\right)^2 \left(\frac{2\text{ GeV}}{m_{\pi_d}}\right) \left(\frac{M_{X_d}}{1\text{ TeV}}\right)^4 .$$

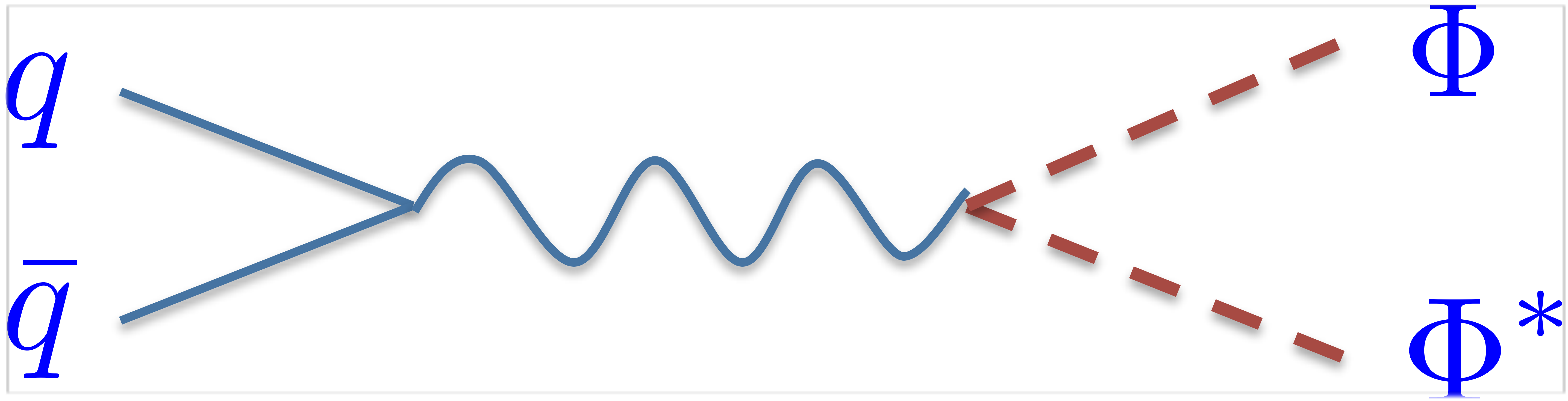

$pp \to Q\overline{Q}$
1m
3m



James Beacham,
ATLAS Dark Sector
Workshop, Cosenza, Italy,
Feb 10, 2016.

PRODUCTION

$$pp \to \Phi\Phi^\dagger \to \bar{q}\, Q_d\, \overline{Q}_d\, q$$



Final state is

- 2 QCD jets
- 2 emerging jets

Cross section is calculable
$\sigma(M_\Phi = 1\,\mathrm{TeV}) \approx 10\,\mathrm{fb}$
@ LHC14

Schwaller, DS, Weiler, arXiv:1502.0409.

DEDICATED CMS SEARCHES

Journal of High Energy Physics
February 2019, 2019:179 | Cite as

Search for new particles decaying to a jet and an emerging jet

Authors | Authors and affiliations

The CMS collaboration, A. M. Sirunyan

M. Dragicevic, J. Erö, A. Escalante Del Valle

Open Access | Regular Article - Experim

First Online: 26 February 2019

arXiv > hep-ex > arXiv:2403.01556

Search...

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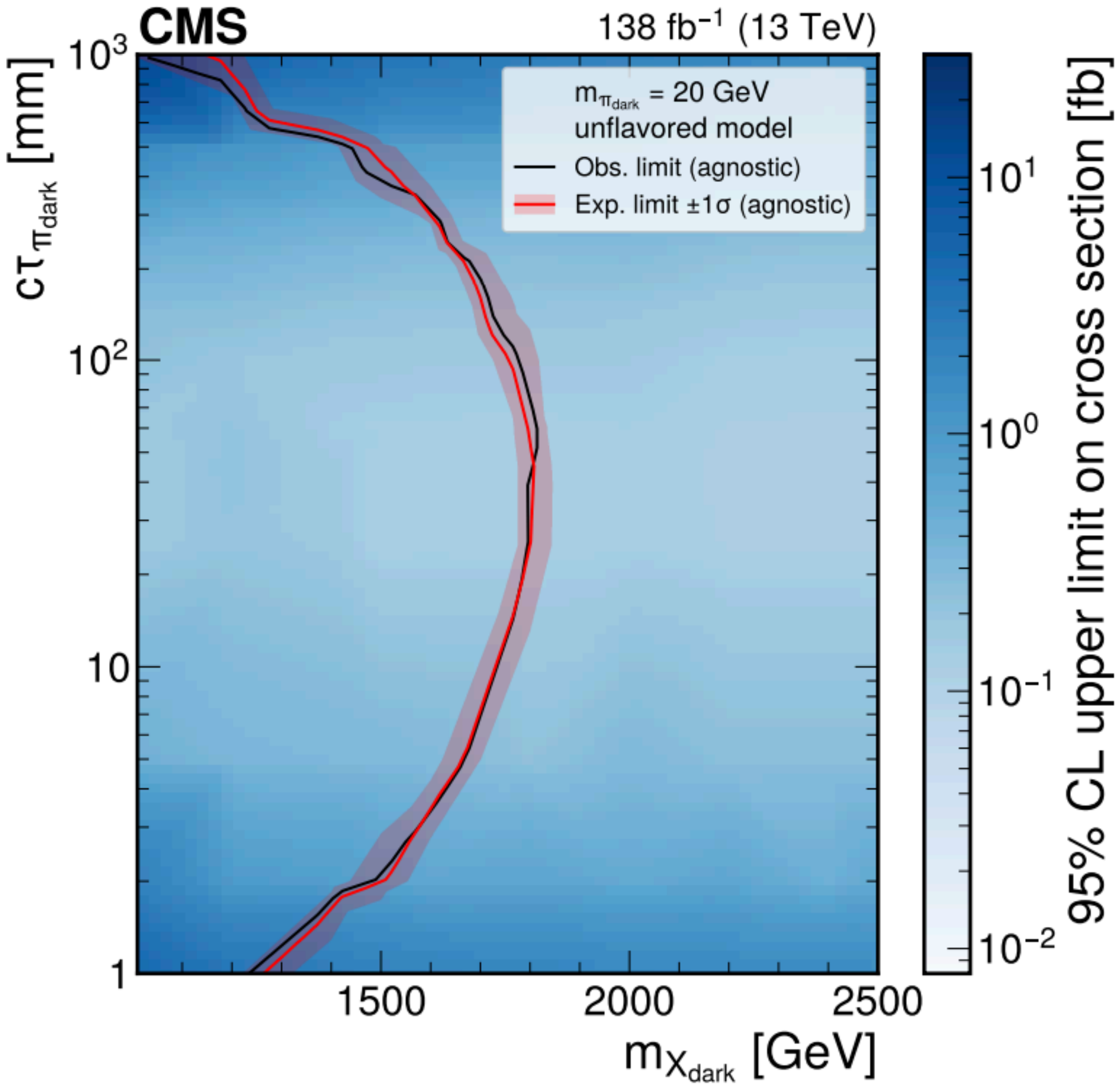
High Energy Physics – Experiment

[Submitted on 3 Mar 2024]

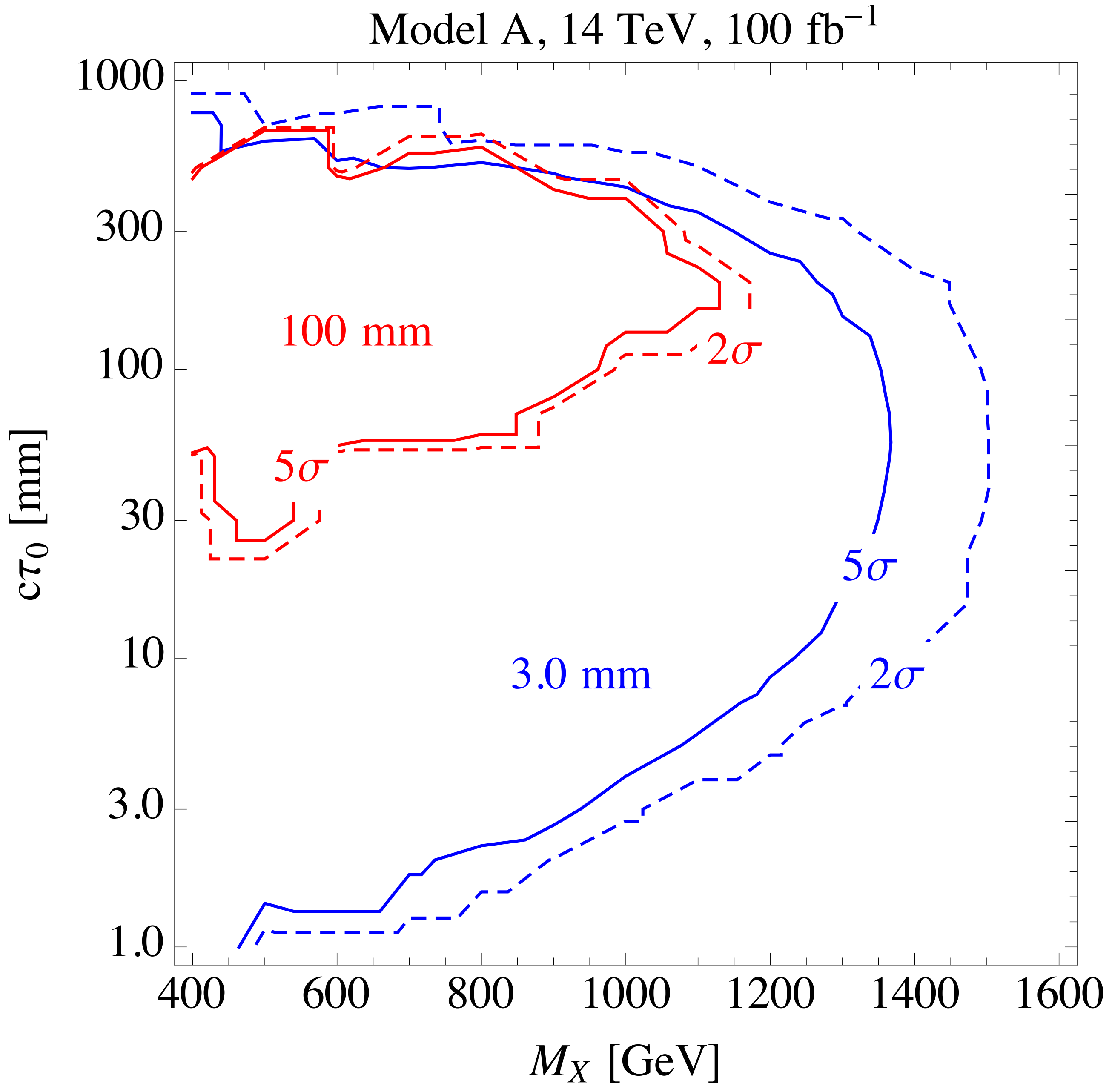
Search for new physics with emerging jets in proton-proton collisions at $\sqrt{s} = 13$ TeV

CMS Collaboration

LIMIT



Our projection:



QCD RESONANCES

•	$\pi^{\pm}$	$1^-(0^-)$
•	π^0	$1^-(0^{-+})$
•	η	$0^+(0^{-+})$
•	$f_0(500)$ aka σ; was $f_0(600)$, $f_0(400-1200)$	$0^+(0^{++})$
•	$\rho(770)$	$1^+(1^{--})$
•	$\omega(782)$	$0^-(1^{--})$
•	$\eta'(958)$	$0^+(0^{-+})$
•	$f_0(980)$	$0^+(0^{++})$
•	$a_0(980)$	$1^-(0^{++})$
•	$\phi(1020)$	$0^-(1^{--})$
•	$h_1(1170)$	$0^-(1^{+-})$
•	$b_1(1235)$	$1^+(1^{+-})$
•	$a_1(1260)$	$1^-(1^{++})$
•	$f_2(1270)$	$0^+(2^{++})$
•	$f_1(1285)$	$0^+(1^{++})$
•	$\eta(1295)$	$0^+(0^{-+})$
•	$\pi(1300)$	$1^-(0^{-+})$
•	$a_2(1320)$	$1^-(2^{++})$
•	$f_0(1370)$	$0^+(0^{++})$

•	$\rho_3(1690)$	$1^+(3^{--})$
•	$\rho(1700)$	$1^+(1^{--})$
•	$a_2(1700)$	$1^-(2^{++})$
	$a_0(1710)$	$1^-(0^{++})$
•	$f_0(1710)$	$0^+(0^{++})$
	$X(1750)$	$?^-(1^{--})$
	$\eta(1760)$	$0^+(0^{-+})$
	$f_0(1770)$	$0^+(0^{++})$
•	$\pi(1800)$	$1^-(0^{-+})$
	$f_2(1810)$	$0^+(2^{++})$
	$X(1835)$	$0^+(0^{-+})$
•	$\phi_3(1850)$	$0^-(3^{--})$
	$\eta_1(1855)$	$0^+(1^{-+})$
•	$\eta_2(1870)$	$0^+(2^{-+})$
•	$\pi_2(1880)$	$1^-(2^{-+})$
	$\rho(1900)$	$1^+(1^{--})$
	$f_2(1910)$	$0^+(2^{++})$
	$a_0(1950)$	$1^-(0^{++})$
•	$f_2(1950)$	$0^+(2^{++})$
•	$a_4(1970)$	$1^-(4^{++})$

	$\pi_1(1400)$	$1^-(1^{-+})$
•	$\eta(1405)$	$0^+(0^{-+})$
•	$h_1(1415)$	$0^-(1^{+-})$
•	$f_1(1420)$	$0^+(1^{++})$
•	$\omega(1420)$	$0^-(1^{--})$
	$f_2(1430)$	$0^+(2^{++})$
•	$a_0(1450)$	$1^-(0^{++})$
•	$\rho(1450)$	$1^+(1^{--})$
•	$\eta(1475)$	$0^+(0^{-+})$
•	$f_0(1500)$	$0^+(0^{++})$
	$f_1(1510)$	$0^+(1^{++})$
•	$f_2'(1525)$	$0^+(2^{++})$
•	$f_2(1565)$	$0^+(2^{++})$
	$\rho(1570)$	$1^+(1^{--})$
	$h_1(1595)$	$0^-(1^{+-})$
•	$\pi_1(1600)$	$1^-(1^{-+})$
•	$a_1(1640)$	$1^-(1^{++})$
	$f_2(1640)$	$0^+(2^{++})$
•	$\eta_2(1645)$	$0^+(2^{-+})$
•	$\omega(1650)$	$0^-(1^{--})$
•	$\omega_3(1670)$	$0^-(3^{--})$

	$\rho_3(1990)$	$1^+(3^{--})$
	$\pi_2(2005)$	$1^-(2^{-+})$
•	$f_2(2010)$	$0^+(2^{++})$
•	$f_0(2020)$	$0^+(0^{++})$
•	$f_4(2050)$	$0^+(4^{++})$
	$\pi_2(2100)$	$1^-(2^{-+})$
	$f_0(2100)$	$0^+(0^{++})$
	$f_2(2150)$	$0^+(2^{++})$
	$\rho(2150)$	$1^+(1^{--})$
•	$\phi(2170)$	$0^-(1^{--})$
	$f_0(2200)$	$0^+(0^{++})$
	$f_J(2220)$	$0^+(2^{++}$ or $4^{++})$
	$\omega(2220)$	$0^-(1^{--})$
	$\eta(2225)$	$0^+(0^{-+})$
	$\rho_3(2250)$	$1^+(3^{--})$
•	$f_2(2300)$	$0^+(2^{++})$
	$f_4(2300)$	$0^+(4^{++})$
	$f_0(2330)$	$0^+(0^{++})$
•	$f_2(2340)$	$0^+(2^{++})$
	$\rho_5(2350)$	$1^+(5^{--})$
	$X(2370)$	$?^?(?^{??})$

PDG

THANK YOU

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Unitarity in the SM at high energy:
Lee, Quigg, Thacker, '77

Interference in VV -> VH:
Theory, ATLAS, CMS

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Supersymmetry Primer

Composite Higgs Review

Extra Dimensions and AdS/CFT

NNaturalness

Weakless Universe

Prediction of cosmological constant